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# Performance Assessment for HLW/SNF Disposal in Salt

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Salt Repository Research, Design and Operations

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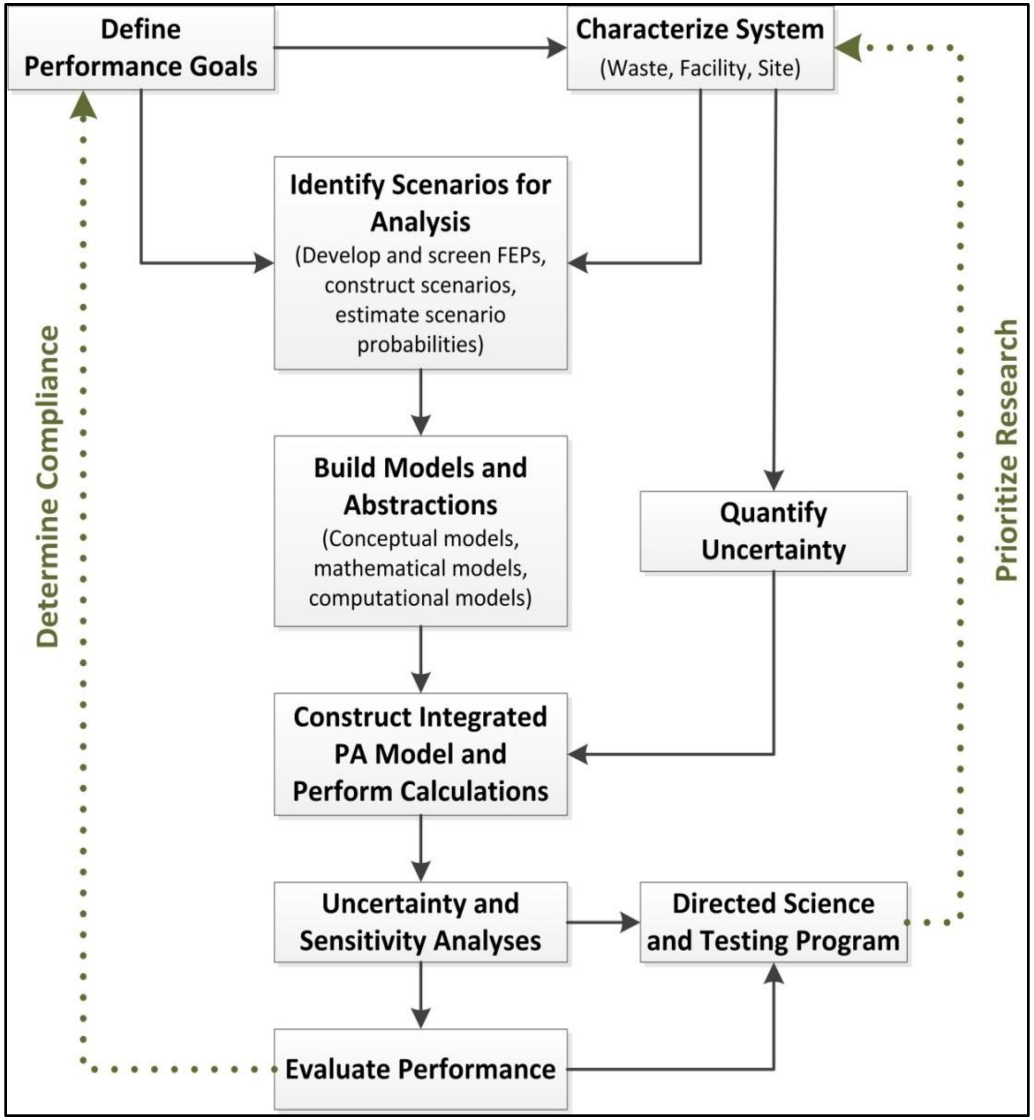
# Outline

- General performance assessment (PA) methodology
- Past Sandia and U.S. Efforts in salt PA
- Current focus on “generic” disposal systems and geologic media
- HLW/SNF salt host rock TSPA model development methodology—scope for FY 2012
- Site/design reference case definition
- Sensitivity analyses to support FEPs exclusion
- Mapping of included FEPs to PA model components, by major process and domain
- Future work:  model framework and computational framework design/requirements
- Possible areas for U.S.-German collaboration

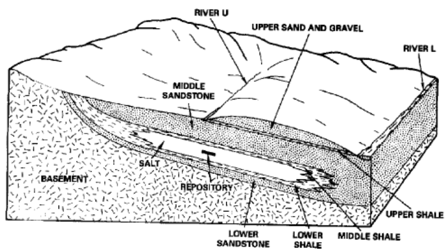
# Performance Assessment (PA) Methodology

- Formal structure to guide **iterative** quantitative post-closure assessments:
  - Goals & site/design →
  - PA→
  - UA/SA →
  - R&D →
  - Site/design in next phase



# Previous U.S. & Sandia Efforts in Salt PA

1) Sandia's "Risk Methodology for Geologic Disposal of Radioactive Waste," Campbell et al. 1978—applied to a "generic" or "reference" bedded salt repository for HLW, ILW, and LLW



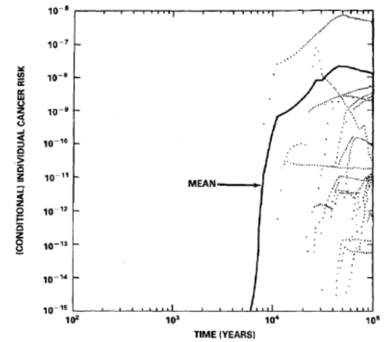
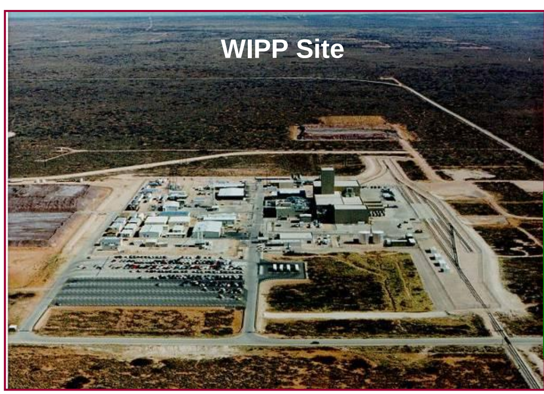




Figure 3.6.5. Variation in Individual Cancer Risk for Scenario 3

2) Salt Repository Project (SRP), Deaf Smith County, TX: "Postclosure performance assessment of the SCP (Site Characterization Plan) conceptual design for horizontal emplacement: Revision 1," ONWI (Office of Nuclear Waste Isolation) 1987b

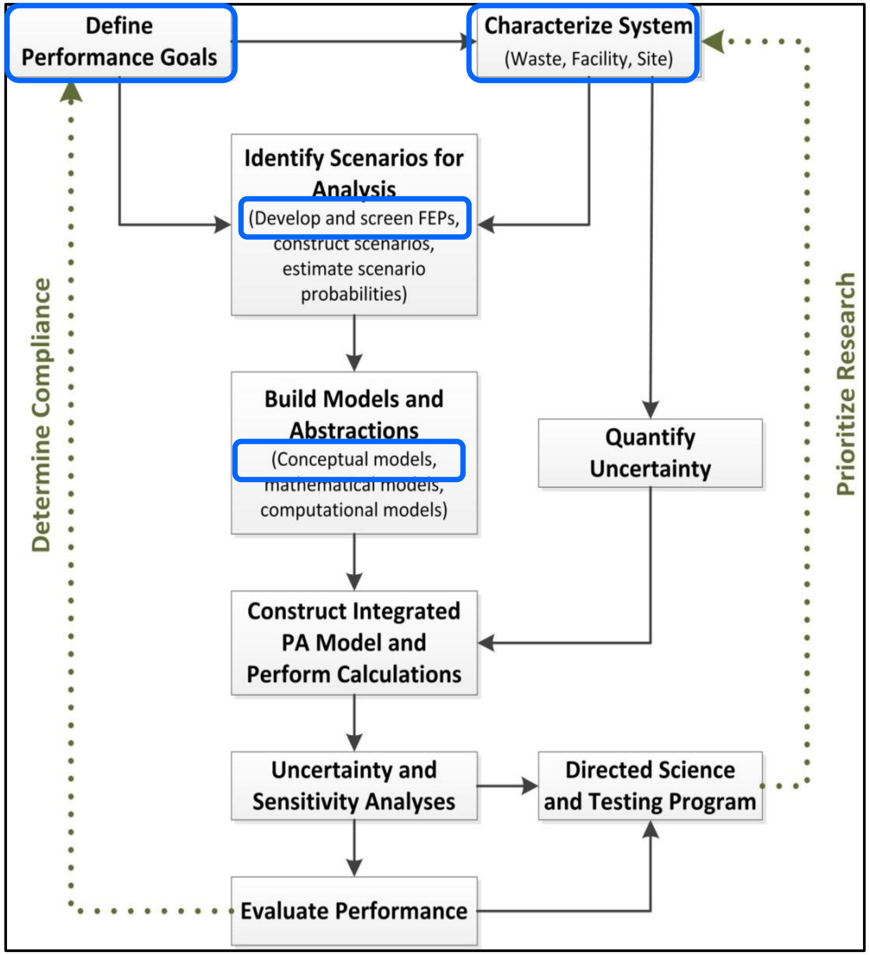
3) Waste Isolation Pilot Plant (WIPP) for defense TRU waste, Compliance Certification Application (CCA) Performance Assessment, DOE 1996



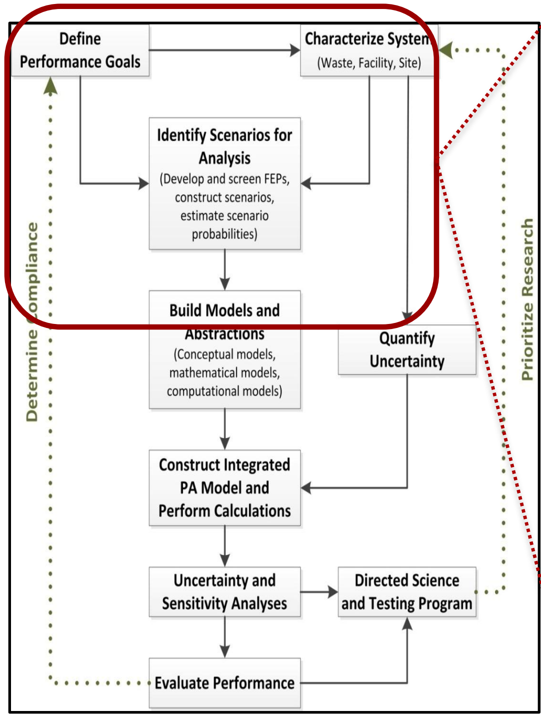

- Initially sited – 1975
- Certified by the EPA – 1998
- First Waste Receipt – March 26, 1999
- First Recertification – March 2006
- Second Recertification – November 2010
- More than 10,000 shipments to date

# HLW/SNF Salt PA Model Activities in FY 12

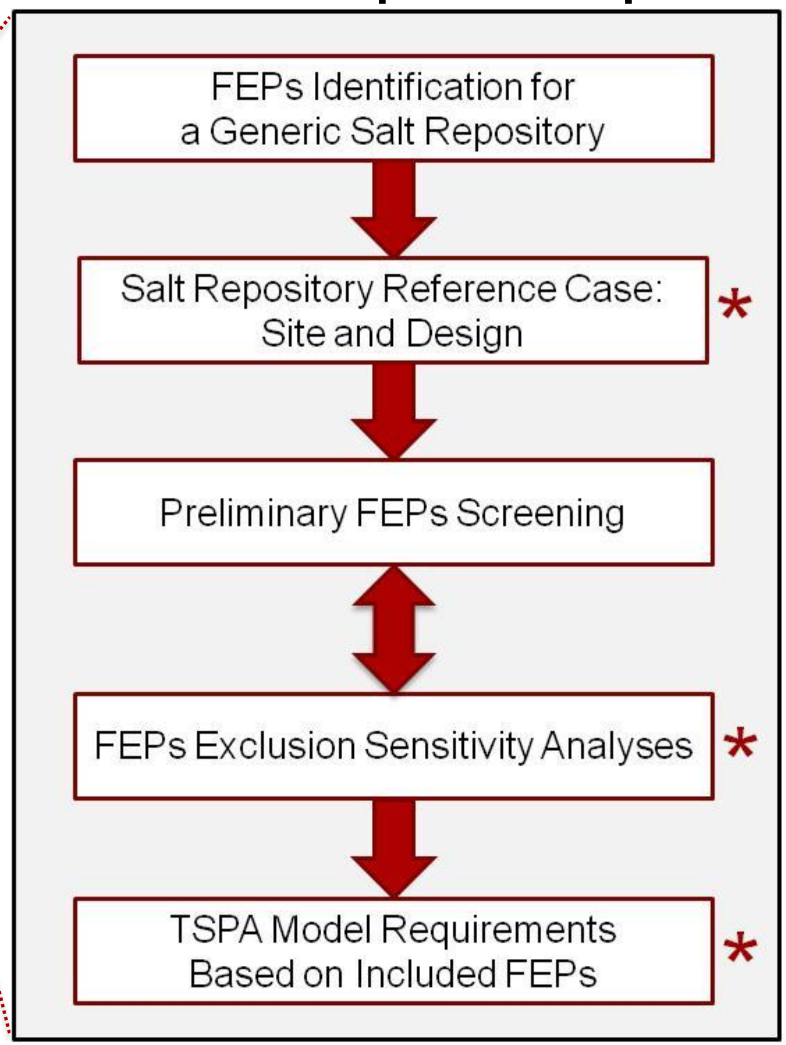
- Until new U.S. disposal policy is established, the DOE storage and disposal RD&D program will focus on "generic" repository systems in various media (granite, shale, salt)
- An generic salt PA model was designed (Clayton et al. 2011) but was isothermal, with limited process couplings
- New generic *salt* disposal PA model development is focusing on model <u>requirements</u>, using:
  - Generic performance standards
  - Generic site/design
  - FEP screening evaluations for a generic salt reference site/design
  - Methodology/requirements for ensuring key FEPs inclusion in component PA models, and key process couplings within and among component models



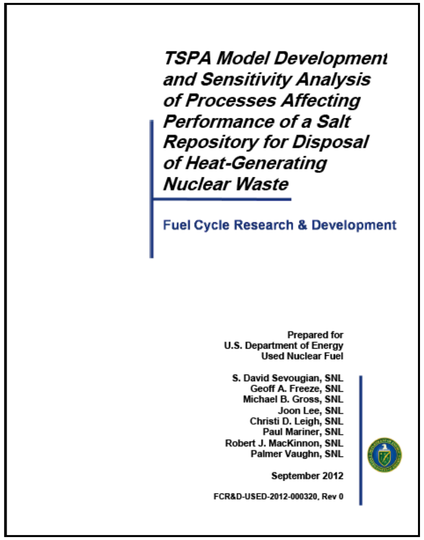
# Methodology for Salt TSPA Model Development—Scope for FY 2012




**FY12 Development Scope**




2012 Milestone Report



*TSPA Model Development and Sensitivity Analysis of Processes Affecting Performance of a Salt Repository for Disposal of Heat-Generating Nuclear Waste*

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Nuclear Fuel

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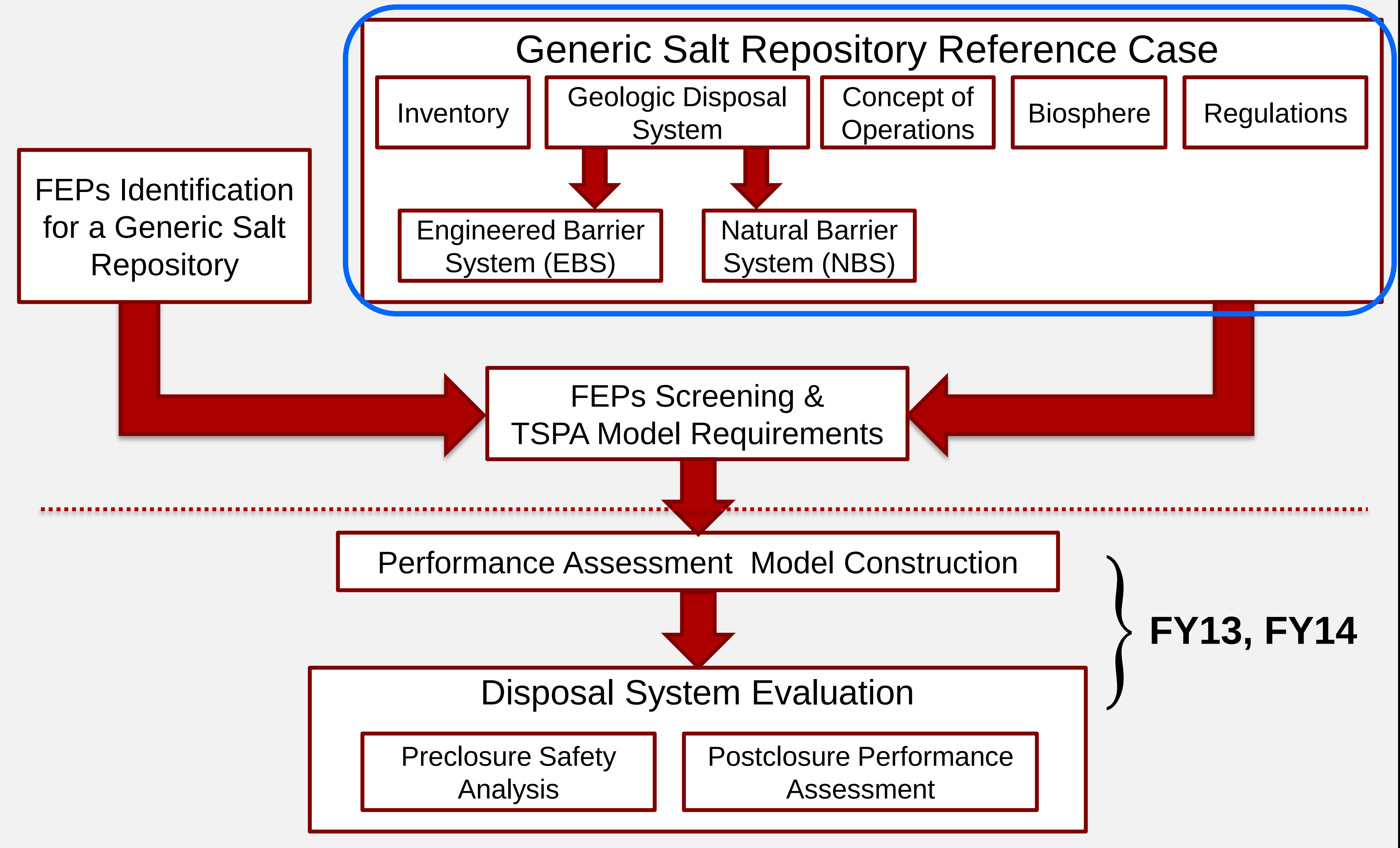
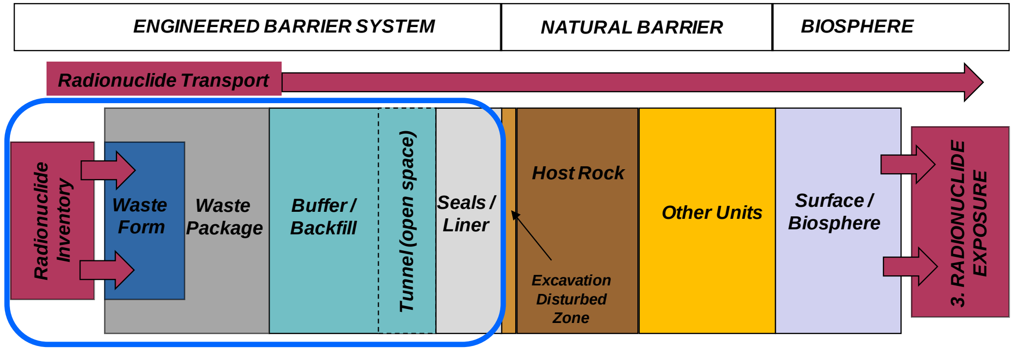
September 2012

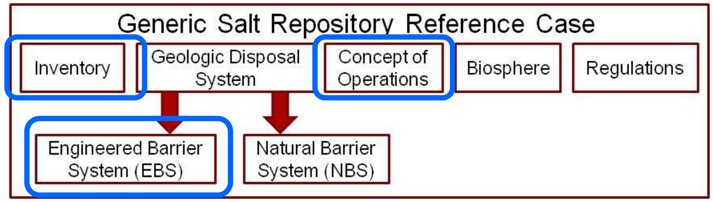
FCR&D-USED-2012-000320, Rev 0

# Generic Salt Repository Reference Case



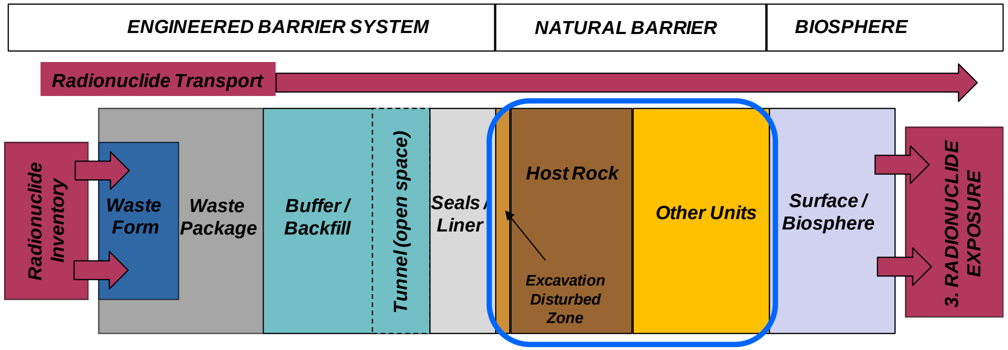
# EBS Specification for Reference Case

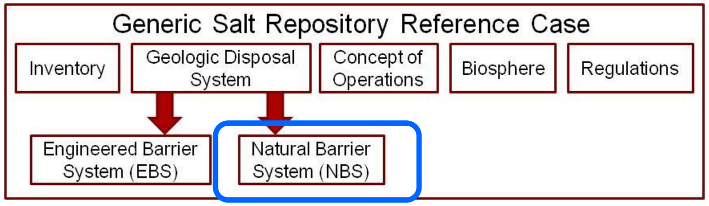



- <u>Waste form & inventory</u> for "no replacement scenario": Carter et al. 2012a, 2012b
- <u>Waste package</u> overpack of carbon steel (A216 or A516): thick enough to be recovered after 300 years in 18 MPa lithostatic: ONWI 1987a, Hardin et al. 2012
- <u>Repository layout and waste package emplacement</u> in alcoves (hot waste) or on floor (cool waste): Hardin et al. 2012
- <u>Thermal management</u> such that 12-PWR SNF packages can be used (after sufficient decay storage) so as not to exceed 200°C at drift wall: Hardin et al. 2012
- <u>Backfill</u> of slightly compacted crushed salt (35% porosity): Rothfuchs et al. 2003
- <u>Tunnels</u> sufficient for 1.3 m by 5 m 12-PWR packages: Hardin et al. 2012
- <u>Seal system</u> similar to WIPP, with crushed salt for long-term and concrete/asphalt for short-term: DOE 2006

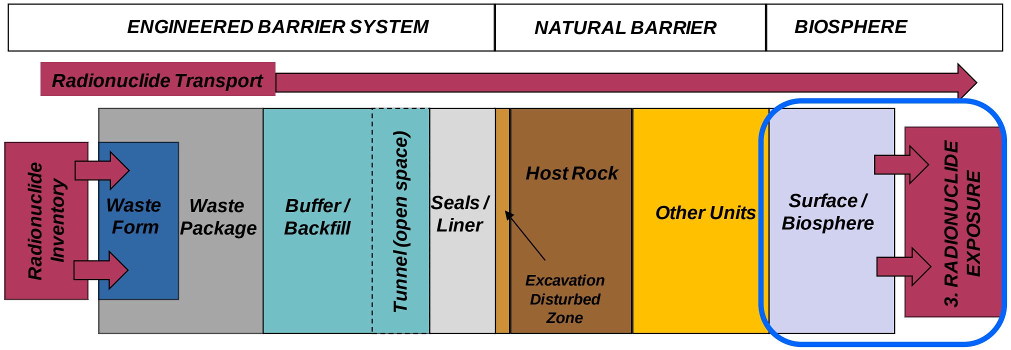
# NBS Specification for Reference Case

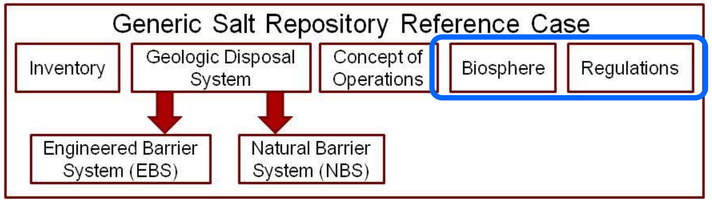



- <u>Geologic Setting</u> such that bedded salt host formation could be found in any of five major depositional basins in the U.S.: see Pierce and Rich 1958, Pierce and Rich 1962, and Johnson and Gonzales 1978
- <u>Excavation Disturbed Zone (EDZ):</u> see Hansen and Leigh 2011 for likely evolution
- <u>Host rock salt</u> formation properties defined, including depth to top of salt, salt bed thickness, lateral extent of salt bed, stratigraphic dip, interbed thickness and location, and brine chemistry: Sevougian et al. 2012
- <u>Other geologic units</u> including overlying aquifer properties, and properties of an overpressure zone beneath salt bed (human intrusion scenario): Sevougian et al. 2012

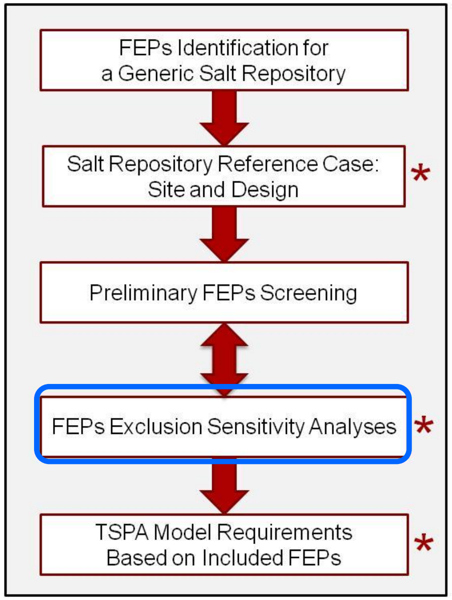
# Biosphere/Regulations for Reference Case



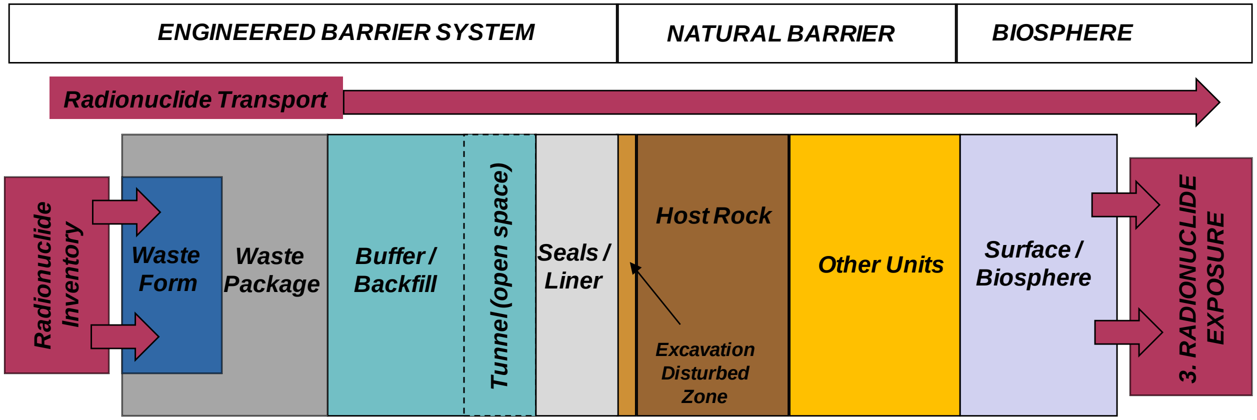




- <u>Biosphere</u> based on IAEA BIOMASS Example Reference Biosphere 1 (ERB1) dose model, and assumes certain other properties, including repository fluid discharge rate into an aquifer, aquifer dimensions and flow and transport properties, water well rate, water consumption rates, and ingestion dose coefficients: IAEA 2003
- <u>Generic regulatory environment</u> uses existing regulations (40 CFR 191) modified to include the risk-informed approach of 40 CFR 197:
  - 10,000-year screening of most FEPs, except 1,000,000 years for certain events, such as climate change (40 CFR 197)
  - Dose-based (40 CFR 197)
  - Waste recoverable for 300 years (40 CFR 191)

# Qualitative or Quantitative Justification for Evaluate/Exclude FEPs




- Categorize the "evaluate" and "exclude" FEPs by major physical-chemical processes:* R-T-M-H-Tr-C-B
- Determine if "evaluate"/"exclude" categorization can be justified with a qualitative reasoned argument or whether a quantitative sensitivity analysis is required
- Classify sensitivity analyses by model feature/domain and by model/software type (e.g., existing THM process model, new THMC process model, existing TSPA model, enhanced existing TSPA model, or a bounding analysis)



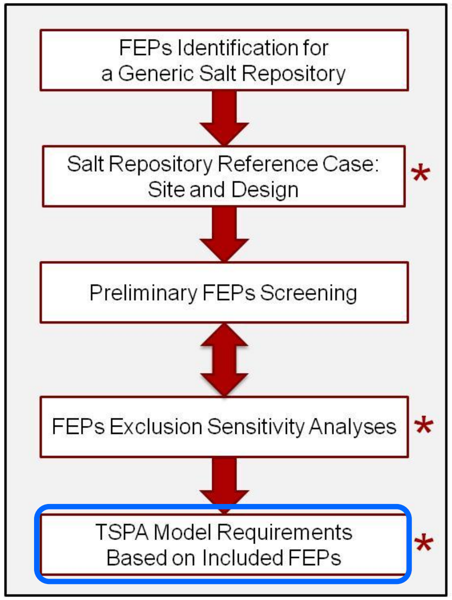

*(R = Radiological Decay and Ingrowth; T = Thermal; M = Mechanical; H = Hydrological; Tr = Transport; C = Chemical; B = Biological)

# Sensitivity Analyses Proposed for Justification of "Evaluate" or "Exclude" FEPs

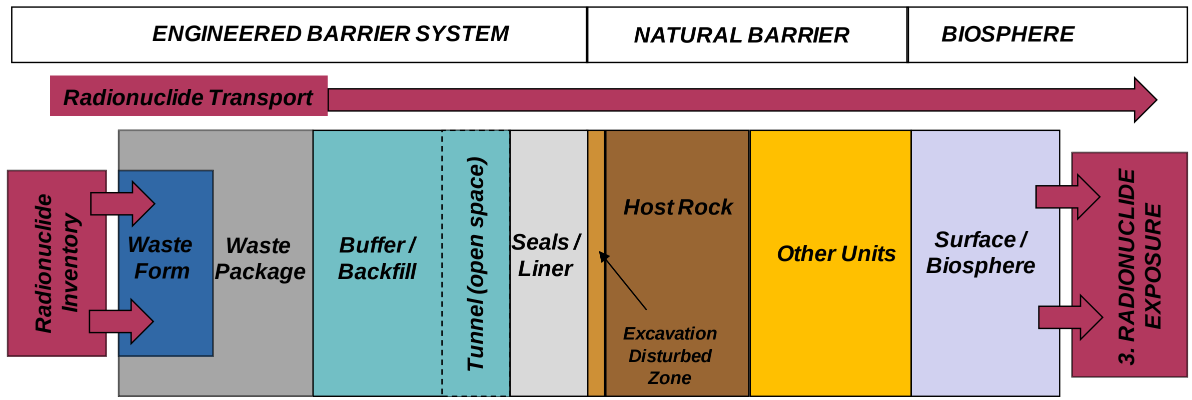
| UFD FEP Number | Description | Related Feature or Component | Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A | Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded" | Relevant Process for Calculations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R | T | M | H | Tr | C | B |
| 2.1.03.00 | 1.03. WASTE CONTAINER | | | | | | | | | | |
| 2.1.03.01 | Early Failure of Waste Packages | - Waste Package | **Evaluate** impact of early waste package failures on chemistry of brine in backfill/tunnels and on early radionuclide releases from EBS | **EBS-5:** Thermal-Chemical Calculations for Chemistry of Brine in Waste Package, Backfill, and Tunnels After Waste Package Failure<br><br>**Model**: Existing T-C process model | | ✓ | | | | ✓ | |
| 2.1.08.00 | 1.08. HYDROLOGIC PROCESSES | | | | | | | | | | |
| 2.1.08.05 | Flow Through Liner / Rock Reinforcement Materials in EBS | - Tunnel/Liner | **Likely Excluded** | Provide a **reasoned argument** that flow through these EBS components are not important, based on the use of minimal ground support in the emplacement drifts, per the salt disposal reference case. | | | | | | | |
| 2.1.08.07 | Condensation Forms in Repository<br>- On Tunnel Roof / Walls<br>- On EBS Components | - Waste Package<br>- Buffer/Backfill<br>- Tunnel<br>- Seals<br>- EDZ | **Evaluate** | **EBS-9:** Thermal-Hydrological-Chemical Calculations for Dryout and Rewetting of emplacement drifts<br><br>**Model:** New coupled T-H-C process model | | ✓ | | ✓ | | ✓ | |

(R = Radiological Decay and Ingrowth; T = Thermal; M = Mechanical; H = Hydrological; Tr = Transport; C = Chemical; B = Biological)

# Mapping of Included FEPs to PA Feature/ Component Models (Spatial Domain)




- Define the major physical-chemical processes (T-H-M-C-R-Tr-B) to be included in each PA component model based on FEPs screening




- Review/analysis of included FEPs to decide how to include them in the PA component models (in FY 2013):
  - High-fidelity
  - "Lumped" = reduced dimensionality or simplified representation (limited multi-physics coupling)
  - Response surface

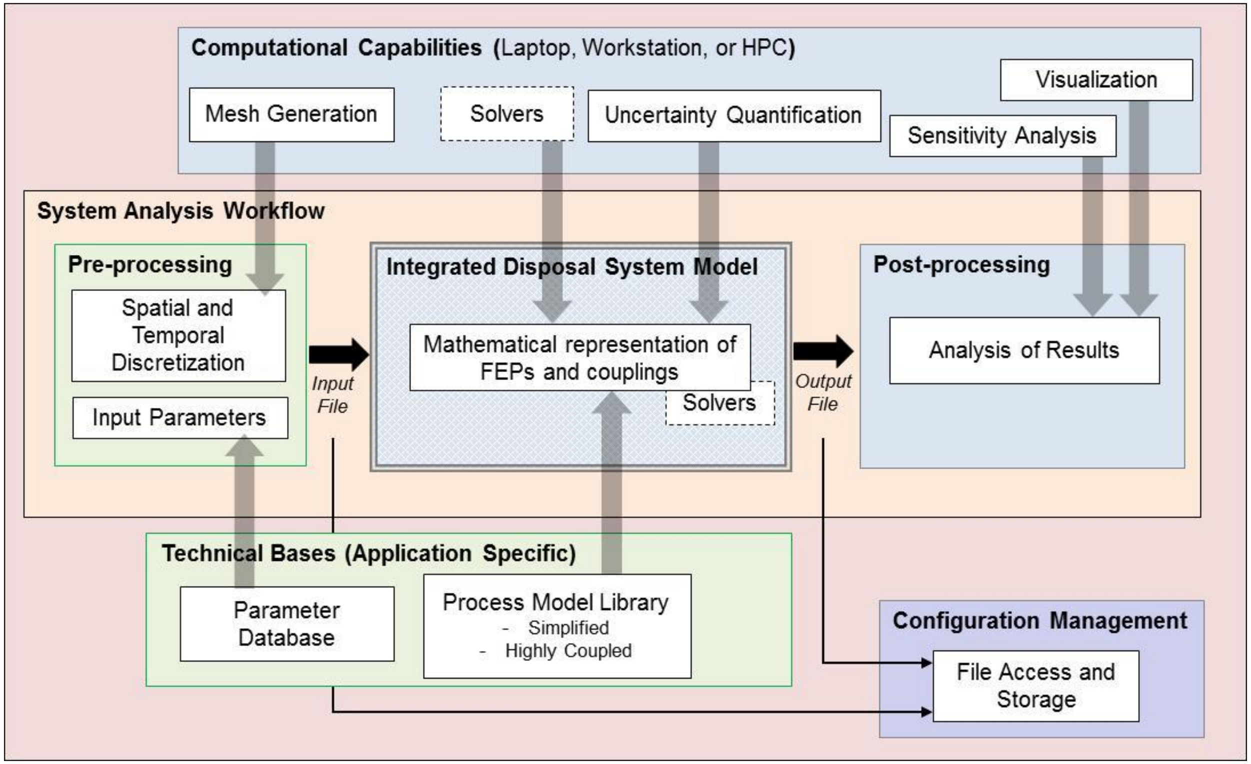
# Mapping of Included FEPs to **Waste Package Structural Response Model**

**Table 3. Models for Structural Response of the Waste Package, Based on Included or Likely Included FEPs**
(R = Radiological Decay and Ingrowth; T = Thermal; M = Mechanical; H = Hydrological; Tr = Transport; C = Chemical)

| UFD FEP Number | FEP Description | Notes | R | T | M | H | Tr | C |
|---|---|---|---|---|---|---|---|---|
| **CORE MODEL FOR STRUCTURAL RESPONSE OF THE WASTE PACKAGE:** | | | | | | | | |
| 2.1.07.02 | Drift Collapse | | | ✓ | ✓ | | | |
| 2.1.07.03 | Mechanical Effects of Backfill | Backfill consolidation around waste package | | ✓ | ✓ | | | |
| 2.1.07.05 | Mechanical Response of Waste Packages | | | | ✓ | | | |
| 2.1.11.01 | Heat Generation in EBS | | | ✓ | | | | |
| 2.1.11.03 | Effects of Backfill on EBS Thermal Environment | | | ✓ | ✓ | | | |
| 2.1.11.07 | Thermal-Mechanical Effects on Waste Packages | | | ✓ | ✓ | | | |
| 2.1.11.08 | Thermal-Mechanical Effects on Backfill | | | ✓ | ✓ | | | |
| **CORE MODEL FOR STRUCTURAL RESPONSE OF THE WASTE PACKAGE COUPLED WITH FLOW:** | | | | | | | | |
| 2.1.08.03 | Flow in Backfill | Determines brine availability during consolidation | | | | ✓ | | |
| 2.1.08.08 | Capillary Effects in EBS | Determines brine availability during consolidation | | | | ✓ | | |
| **CORE MODEL FOR STRUCTURAL RESPONSE OF WASTE PACKAGE COUPLED WITH FLOW & CORROSION OF WASTE PACKAGE OVERPACK:** | | | | | | | | |
| 2.1.03.02 | General Corrosion of Waste Packages | Thickness of waste package overpack | | ✓ | | ✓ | | ✓ |
| 2.1.03.04 | Localized Corrosion of Waste Packages | Integrity of overpack when pits/cracks form | | ✓ | | ✓ | | ✓ |

# Future Design of Salt TSPA Model

- The TSPA model is comprised of two main components:
  - a generic multi-physics model framework that facilitates inclusion of conceptual and mathematical models of the key included FEPs
  - a computational framework that facilitates integration of system analysis workflow (e.g., pre-processing, numerical integration, post-processing) with support capabilities (e.g., mesh generation, UQ, HPC)



# Proposed Areas for Collaboration

- Methodology for determining what physical-chemical processes and process couplings are needed in a salt PA model:
  - How should T-H-M-C-R-B-Tr processes be represented in a system PA model that represents uncertainty with multiple realizations of system performance?
  - Three-dimensional T-M-H processes are clearly important at early times but can they simply be abstracted for representation in the system PA, and how?
- Methodology for R&D prioritization:
  - More formally define how to use the safety case to prioritize future R&D
  - Methods for using PA, and associated uncertainty/sensitivity analyses, for prioritizing R&D
  - Decision analysis models/methods/software have been used in other fields to prioritize R&D activities and R&D "portfolios" (or groups of activities), based on cost/benefit, and including constraints:
    - Can we adapt decision analysis techniques to develop a robust methodology to guide repository science and R&D?